MARKERLESS MOTION CORRECTION IN MRI

Rasmus Ramsbøl Jensen[1,2], Claus Benjaminsen[1,2], Adam Espe Hansen[2], Rasmus Larsen[1], and Oline Vinter Olesen[1,2]
[1]*DTU Compute, Technical University of Denmark, Lyngby, Copenhagen, Denmark,* [2]*Department of Clinical Physiology, Nuclear Medicine & PET, Rigshospitalet, Copenhagen, Denmark*

Purpose: In brain imaging with ever improving scanner quality and resolution, image deterioration due to head motion is a continuing and growing problem. Especially in fMRI, diffusion tensor imaging, and dynamic PET, where low SNR can be a challenge, long acquisition times are needed, and motion can be confounded with physiological changes. In specific cases such as high field static MR the image resolution can be a few tenths of a millimeter and even small respiratory motions can cause artefacts [1]. Many motion correction techniques have been suggested but no single device or method solves the problem in a routine clinical use. We propose a method for accurate motion correction in MRI through markerless tracking. It is the first time markerless tracking is used to correct MRI images. The method has the potential to seamlessly fit the clinical workflow with no added complexity and no errors related to marker attachment on the patient's head. It is based on an optical surface scanner, Tracoline, which is the first remote structured light scanner conveying light through optical fiber bundles [2]. To avoid discomfort from projected light, the system projects near infrared light patterns invisible to the patient. The developed software, TracSuite, continuously aligns the surface scans, which allows for accurate tracking of motion. In this work, we demonstrate our system on the Siemens mMR Biograph 3T by retrospectively aligning EPI images on three scans of a voluntary subject.

Methods: The structured light scanner is designed to produce real time in-bore surface scans. To achieve MR compatibility the electronics are separated from the optical end with image fiber bundles. Only a minimum of components are located in-bore, while the potentially RF emitting and ferromagnetic components are kept out of the bore in a RF shielded box [2].

The system was set up on the Siemens mMR Biograph 3T scanner and 3 EPI sequences of 100 time volumes were acquired of a healthy volunteer (TR = 3000 ms, TE = 30 ms, matrix size = 64×64, pixel size = 3×3 mm^2, slices = 46, slice thickness = 3 mm). During the three sequences the volunteer was instructed to perform sidewise head rotations with respectively: large motion (approx. ±18 degrees/ 50 mm), medium motion (approx. ±7 degrees/ 20 mm), and no motion (< 0.8 degree/ 1 mm). An MPRAGE sequence was used to determine the geometric alignment between the surface scan and the scanner coordinate system. During the MR sequences, the movement was tracked using the Tracoline system (currently scanning surfaces at up to 20 Hz). The tracking, geometric alignment, and a time synchronization between TracSuite and scanner allows for synchronized motion correction of all the EPI 2D image slices. Each slice is corrected by applying a full 3D rigid realignment to a volume interpolated from either the odd or even slices from the current time volume (scanner readout is interleaved) and then extracting only the corrected slice. This allows each slice to be corrected individually with tracking data from the exact acquisition time, while using data from surrounding slices acquired within < 0.1s. Surrounding data is needed to account for out of plane motion. The tracking is done with submillimeter precision and has previously been demonstrated on the Siemens HRRT PET scanner [3].

Results and Discussion: Fig. 1 shows the displacement of the subject estimated using our markerless tracking system during the scan with large motion. The system is able to accurately track through the head coil even during larger motions (in this case up to 5 cm from the initial position). Such tracking curves can provide a valuable quality assurance for the clinician as it provides monitoring of motion during different sequences. Fig. 2 shows the effect of our proposed markerless motion correction. Two slices (rows) averaged over time in the sequence with large motion shows a comparison of uncorrected, corrected, and the difference from left to right, respectively. The corrected slices show as less blurred, improved delineation of the ventricles, and with better definition of contrast between grey and white matter. The difference images also show that the subject has moved from the initial position, which implies that regions selected in the initial volume, would now be located incorrectly. As a measure of performance, we have calculated the correlation between each of the 100 time volumes and the sequence average. This has been done for the three studies with variation in motion for both uncorrected (red) and corrected (green) results. Fig. 3 clearly shows that adding markerless motion correction can improve quality in the event of motion (top and middle), while motionless data remain the same (curves are overlapping in the bottom plot).

Conclusion: A unique markerless tracking system has been applied for MRI brain motion correction with retrospective slice-by-slice realignment of EPI scan. The motion corrected images were significantly improved visually and quantitatively demonstrating a functioning motion correction pipeline based on markerless tracking. Markerless tracking is a giant leap towards a motion correction scheme providing robust and accurate tracking without adding complexity to the clinical workflow. Our method can be used to correct both PET and MR data on the integrated system.

References:

[1] J. Schulz, T. Siegert, E. Reimer, C. Labadie, J. Maclaren, M. Herbst, and M. Zaitsev R. Turner, "An embedded optical tracking system for motion-corrected magnetic resonance imaging at 7T," Mag. Res. Materials in Phy., Bio. and Med., 2012

[2] O. V. Olesen, J. Wilm, A. van der Kouwe, R. R. Jensen, R. Larsen, L. L. Wald, "An MRI Compatible Surface Scanner," ISMRM-ESMRMB Annual Meeting, No. 1303, 2014

[3] O. V. Olesen, J. M. Sullivan, T. Mulnix, R. R. Paulsen, L. Højgaard, B. Roed, R. E. Carson, E. D. Morris, and R. Larsen. "List-mode PET motion correction using markerless head tracking: proof-of-concept in human studies," IEEE TMI, vol. 32, 200-209, 2013

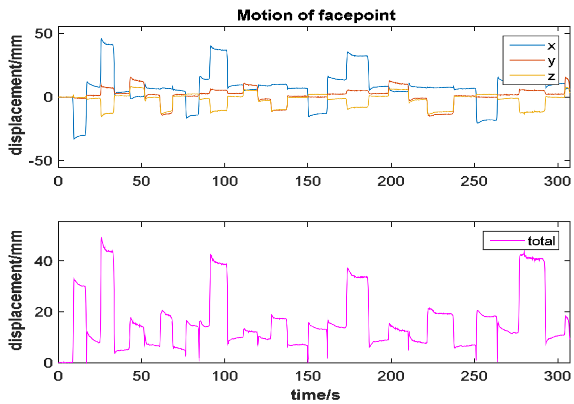

Figure 1: Displacement (axiswise and total) of a mean point on the subject's face for the scan sequence with large motion (~50 mm).

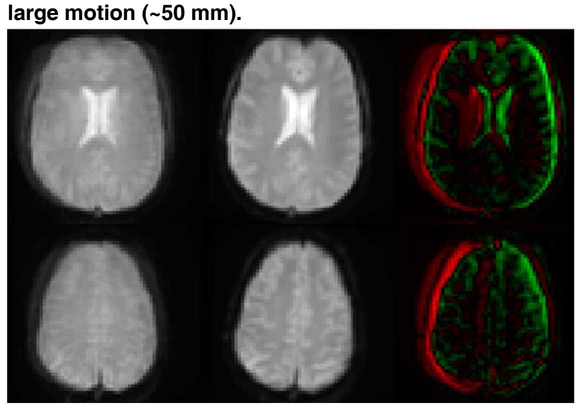

Figure 2: Slices averaged over time in the EPI sequence with large motion. From left: uncorrected, corrected, and difference (signed as red and green).

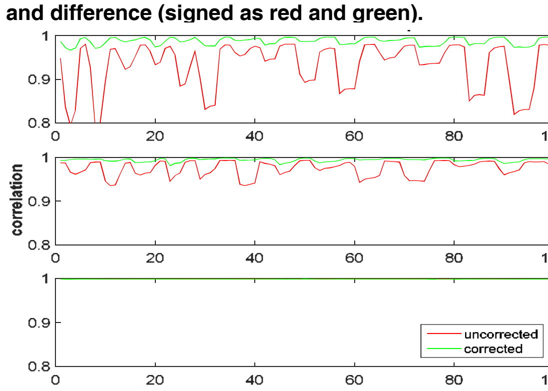

Figure 3: The correlation between each of the 100 volumes and their average over time. Subject movement from the top: large motion, medium motion, no motion. The sequences with movement improved significantly from motion correction.